Magnetic Matching of Ultra-Compact Marx Generator

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LNL has produced a family of ultra-compact Marx-type high-voltage generators (UCMG) for a variety of special pulsed-power applications, such as drivers for compact x-ray sources and high-power RF sources.

The UCMG incorporates low-profile, low-inductance capacitors and switches, high-energy-density ceramic materials, high-electrical-strength dielectric materials, optimally shaped parts, and integrated packaging techniques to achieve higher performance in relatively small packages. As with any pulsed-power source, energy transfer can be improved by matching the impedance of the driver to the load. Load matching can be achieved by saturable reactance ferrites, to provide a nonlinear transition from high to low impedance during the rise time of the UCMG output current.

Project Goals

The primary goal of this project was to perform a proof-of-concept demonstration of the magnetic matching of the UCMG. An underlying objective was to explore the basic properties and response of ferromagnetic materials under very high electrical stress and fast-pulsed conditions. A further objective was to create representative core models for circuit modeling of the UCMG for particular applications.

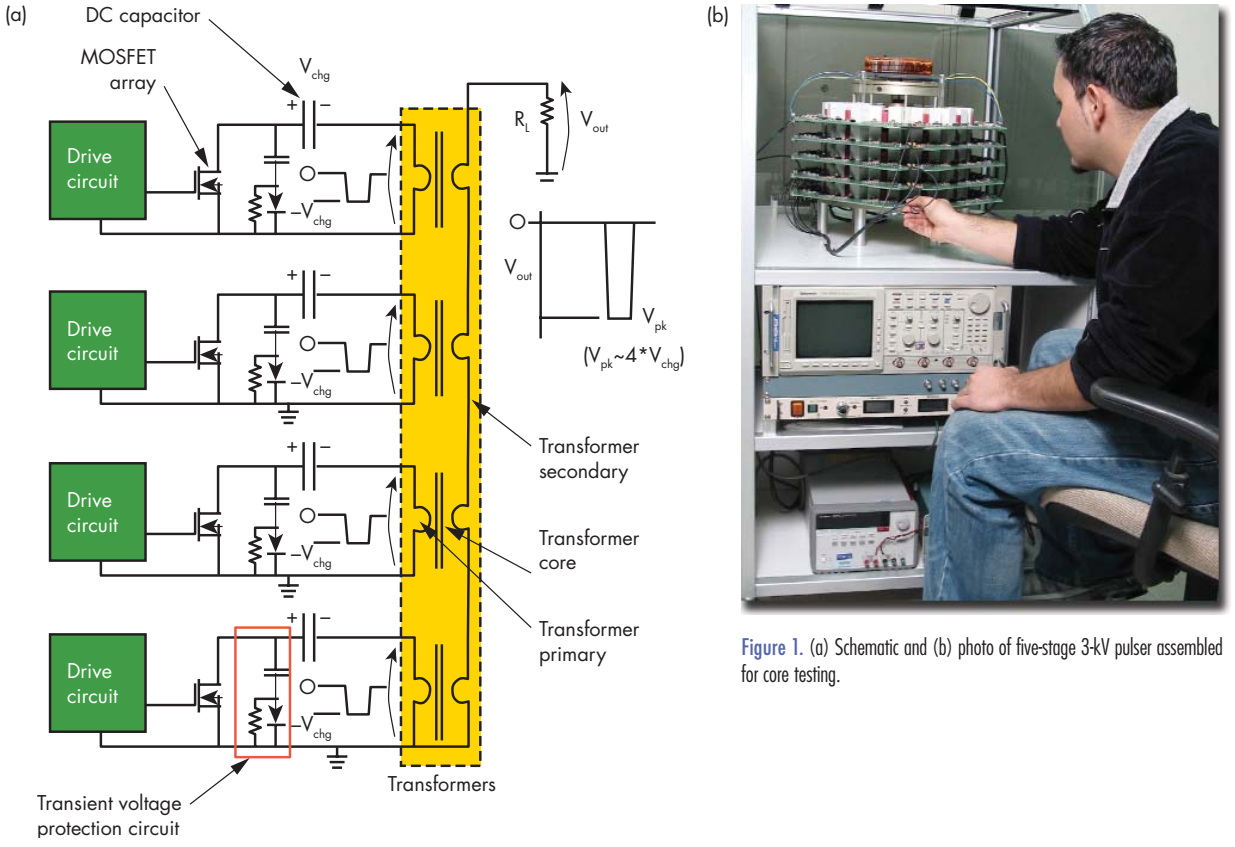

Figure 1. (a) Schematic and (b) photo of five-stage 3-kV pulser assembled for core testing.

Relevance to LLNL Mission

The UCMG is the enabling technology for a new high-performance flash x-ray source for subcritical experiments that are performed in underground alcoves at NTS. This source can be improved by using ferrite materials to suppress prepulse, and by providing better matching to the rod-pinched x-ray diode. The UCMG is also useful for other pulsed-power applications of interest to DNT, NAI, and other government agencies.

FY2004 Accomplishments and Results

We successfully completed the tasks we set for FY2004.

We chose CMD5005 from Ceramic Magnetics as the material to benchmark in our experiments. The manufacturer's specifications for CMD5005 are as follows:

- initial permeability: 1600
- maximum permeability: 4500 typ
- maximum flux density: 0.3 Tesla min
- remnant flux density: 0.18 Tesla max
- coercive force: 0.23 Oe max.

The B-H curves were derived using both AC and pulsed sources. The AC testing was done with a variable frequency power source operated from 60 Hz to 5 kHz. Results from the AC testing were in good agreement with the manufacturer's claims.

For the fast-pulse testing, we adapted hardware from beam kicker applications. A five-stage, 3-kV pulser, shown in Fig. 1, was assembled and operated to survey small toroidal cores. To test larger cores we used an existing 70-stage, 50-kV pulser. Both pulsers produce output pulses with rise times of several nanoseconds and pulse widths up to a microsecond, depending on the load.

In an alternate scheme, the smaller cores were also tested with a single-stage UCMG. In this configuration, the cores are placed around current return rods alongside the generator, as shown in Fig. 2. Excitation current was measured using current viewing resistors at the base of each return rod. Output voltage from a single turn secondary winding around a single core was monitored with differential high-voltage probes. A typical B-H curve derived using this technique is also shown in Fig. 2, as are the effects of adding multiple cores per return rod, increasing the output voltage in proportion to the inductance, until the cores saturate.

For the proof-of-concept demonstration, ferrite cores were added to current return rods around a 10-stage UCMG. Better impedance matching results in higher output power. In the optimized case of 5-×-6 cores, the peak output power is about 2.1×10^9 W, which is about 50% greater than the no-core case.

Core models produced through our special measurements have been incorporated into circuit models that are being used to evaluate improvements in targeted applications.

Related Reference

Goerz, D. A., and M. Wilson, "Ultra-Compact Marx-Type High-Voltage Generator," U.S. Patent 6,060,791 issued May 9, 2000.

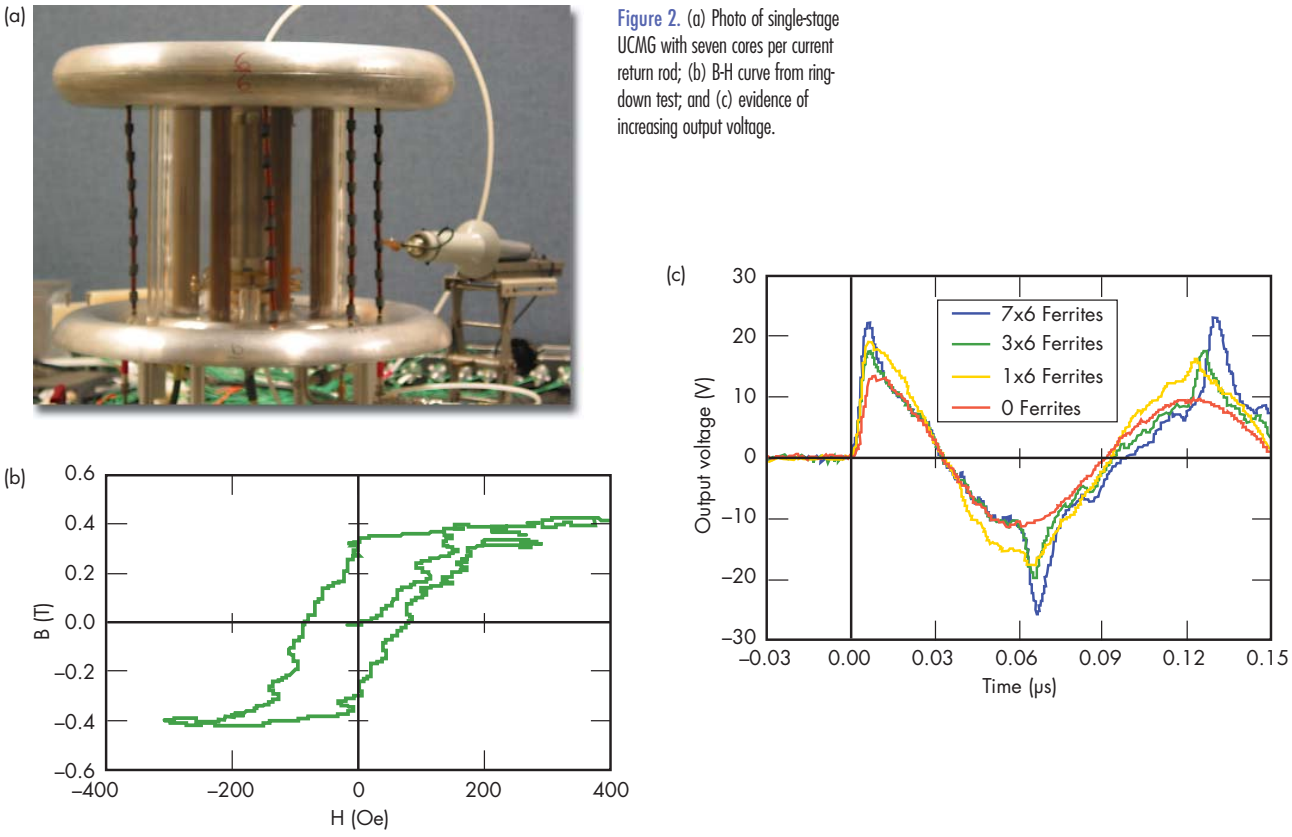

Figure 2. (a) Photo of single-stage UCMG with seven cores per current return rod; (b) B-H curve from ring-down test; and (c) evidence of increasing output voltage.